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CODING SYSTEMS IN PERCEPTION AND COGNITION

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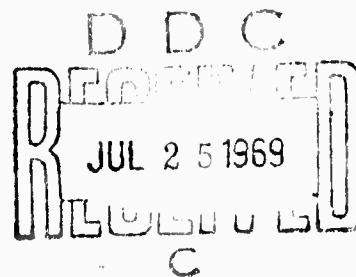
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CODING SYSTEMS IN PERCEPTION AND COGNITION

1. INTRODUCTION

The output of research during the last half of 1968 has continued the
pace set by the previous year. The present report reviews some of the results
from projects which were completed or in progress during this six-month period.
In many ways this period can be viewed as a time of transition. While we
continued to develop the paradigms and themes of the preceding year, we devoted
much of our time towards developing the methodology, hardware and technical
competence to extend our efforts towards new problems. Some of these new
problems include the role of imagery, the control systems of serial behavior,
natural languages, the problem of meaning, decision processes, automated
tasks, skilled performance in naturalistic settings, etc.

Many of these activities which prepare us for new directions are not
reflected in this report; their fruits will become evident only in later
reports. The work that Posner is now doing at the Applied Psychology
Research Unit in Cambridge, England, for example, will hopefully provide us
with the know-how for using analog-digital converters and recorders in our
studies of skilled motor behavior. We will not have such equipment in
operation, however, until at least six months from now. We have also been
devoting much of our manpower to planning ways to implement a time-sharing
system for our computer-aided automatic laboratory. The hardware for this
system cannot be purchased until our next budget period. Some of our
efforts have aimed at preparing for research activities that will take place
after we move into the new psychology building that is scheduled for 1971.
At that time we expect to interface our PDP-9 with the University's large
computer. Consequently, we have already begun to plan the type of laboratory
that can be operated in such a context.

In terms of personnel, the period of this report saw Dr. Posner begin
his leave of absence and take up temporary residence at the Applied Psychology
Research Unit in England. There he began a series of studies that he hopes
will enable him to bring new and more powerful tools to bear upon the study
of coding processes in complex, serial tasks. Meanwhile, Dr. Hyman returned
from Italy and resumed his role as Principal Investigator on September 1.
Since his return,Hyman and his co-workers have initiated new studies in
multidimensional scaling, selective attention, and pattern recognition. Our
Visiting Scholar, Dr. H. K. Beller, completed the first half of his post-
doctoral year with us and has initiated several studies which bridge the
gap between Neisser's ideas about preattentive and focal attentive processes
and Posner's work on the separation of stimulus recognition into different
levels of coding behavior. One of his studies is included in this report;
we expect that some others will be sufficiently far along to be described
in the next report.

During this period two Ph.D. dissertations which were sponsored by our
contract were completed. One was by Dr. William Johnson who is now on the
staff of Whitworth College in Washington; the other was by Dr. Richard Taylor,
who is now a Research Associate at the Veterans Administration Hospital in

Syracuse, New York. Copies of both dissertations are included with this report. Five other Ph.D. dissertations and two M. A. theses are currently in progress under the sponsorship of the project.

In addition to research "findings", our activities during the past six months resulted in some new methods and apparatus that we expect will have application to a wide range of problems relevant to our goals. Some of these new methods and apparatus will be described along with the research findings in the body of this report.

2. PERCEPTION AND PSYCHOPHYSICS

In this section we include studies that deal with how an observer codes information within a single dimension; how he combines information coming simultaneously from two or more dimensions; and how he represents drawings of three-dimensional figures in order to minimize the complexity of the perceptual input. All of these studies emphasize the importance of stimulus variations that can be considered as ranging over one or more "dimensions." The task given to observers in these psychophysical studies is, to be sure, unnatural. In everyday life we do not typically respond directly to the intensities, durations, or qualities of the objects we perceive. Instead, we respond directly to the objects which may be characterized by values on one or more dimensions such as brightness, hue, size, etc. The dimensions or coordinates of the perceptual field are "silent" parts of coding systems. Except when our attention is specifically directed to it, we usually are not aware of the dimensional framework that accompanies our perceptions.

Yet, such frameworks do accompany our perceptions and apparently form an indispensable background for them. When such frameworks are removed or are absent, bizarre effects are the rule. Our colleague, Dr. Beck has reviewed many of the factors that produce the autokinetic effect (Beck, 1969). An important fact is that all of these factors can operate only when the spatial coordinates are lacking or disturbed. Attneave and Reid (1968) have reported on the importance of the phenomenal orientation in perceiving. One purpose, then, of the studies in this section is to uncover more infor- mation about the role of dimensions and coordinate systems in coding behavior.

Another very important goal of such studies is to find ways to better use the observer, himself, as a measuring instrument. In the psychophysical procedures used here we require the observer to either provide us with a number that reflects the magnitude of some sensation (magnitude production) or we ask him to provide us with a stimulus that has a certain sensory effect (stimulus production). In either case we want to use the magnitude of the reported number or the chosen stimulus as a measure of something psycho- logical. Our studies, in part, aim to provide us criteria for assessing the degree to which, in fact, the observer's responses fulfill the necessary conditions to be treated as numbers. With such criteria, we can then discover the conditions under which our observers can be reasonably expected to produce responses that can be used as measures. Perhaps such criteria will also enable us to find suitable corrections to apply; or they will guide us towards training observers to provide responses that are useful measures.

Up to now we have had great success in applying reaction time measures to various problems being investigated under this contract. One feature of such latency measures is that they provide us with large amounts of information from each response. Many judgment and choice experiments, however, provide only a binary measure on each trial--correct or incorrect, left or right, bigger or smaller, etc. If we can discover ways to replace this yes-no judgment with a quantitative measure, the efficiency of such research, as well as the informational return, will go up by several orders of magnitude. Our results, especially with what Fagot calls the "additive law", during the present period have been quite encouraging on this score.

In addition to this interest in measurement, we view the studies in this section as important, not because they may shed light upon the correlation between variations in the physical and phenomenological worlds, but rather, because they provide us important models about the judgmental process itself. We expect that the models that help us to explain how the observer forms a judgment in the psychophysical situations, will also generalize to more complex decision and choice situations. Indeed, Fagot is currently working on both theoretical and empirical techniques for making this extension.

2.1. Unidimensional Psychophysics

Fagot and Stewart (1969a) have completed a study which examines some of the necessary conditions for using judgments of magnitudes and judgments of differences as measures of psychophysical attributes. This is but one of a series of studies which they are conducting to investigate the implicit assumptions underlying such measurement. The dimension being judged was the brightness of a light. In one condition, the observer is shown a stimulus of a given intensity and told to consider that it is of magnitude, say, 100. Then he is shown a series of stimuli at various intensities, one at a time. For each stimulus, he is to assign it a number depending upon its perceived intensity with respect to the standard. If he judges that a particular stimulus is half as bright as the standard, say, then he is to assign it a value of 50. Such a direct method of scaling has been called "magnitude estimation", and it has been employed in a wide variety of psychophysical studies whose results assume that observers can, in fact, assign these numbers in such a fashion that they can be treated as ratio measures of sensory magnitude.

But as Fagot and Stewart point out, the assumption that the observers' numbers fulfill the requirements of ratio measurement is rarely, if ever, tested. One necessary condition can be stated in terms of what Fagot and Stewart call the "product axiom." For all six of their subjects, the product axiom had to be rejected. Even more discouraging, the deviations of the observed magnitude estimations from the axiom showed no systematic trends.

In the second condition, the observers were shown a pair of lights and told to call the difference between them, say, 100. They then assigned numbers to other differences using the first pair as a standard. A necessary condition for such difference judgments to form a measurement scale is that they fulfill an "additive axiom". This axiom was rejected for four of the subjects, but the remaining two subjects seemed to conform fairly well. Furthermore, the deviations of the four nonconforming subjects were found to be systematic in that the judgments tended to exaggerate differences at the high

end of the scale. Such findings are encouraging, because they indicate that at least some subjects can assign numbers to differences in a meaningful way. And the systematic deviations suggest that suitable corrections can be made or that a response bias parameter can be added to the measurement model.

These findings with respect to the difference axiom are in agreement with the findings of Hyman and Well (1967) that in judging differences between pairs of stimulus objects with respect to similarity, subjects can produce numbers that conform to measurement scales, or deviate from them in terms of simple biases that can be taken into account in subsequent interpretations. Much of the work on multidimensional scaling and similarity judgments is based upon the ability of observers to conform to Fagot and Stewart's "difference axiom."

A report of this study which is now in press, is enclosed.

Fagot and Stewart (1969b) have completed a second study, which is also in press, which carefully examines some of the properties of scales based on stimulus production rather than ratio production methods. The attribute again was brightness, but the task for the observer was to set a comparison light so that it appeared half as bright as a standard. The resulting half-judgments were examined in terms of two versions of the power law for psycho-physical functions. The simple version of the power function stated that the psychological magnitude of a stimulus was directly proportional to the intensity of that stimulus raised to some exponent. This simple power function has now been replaced by more complicated functions because, in fact, it does not describe the data.

The version of the power function favored by Stevens and his followers has been called the Phi-law by Fagot and Stewart. This version states that psychological magnitude is proportional to the stimulus-magnitude-minus-a-constant raised to some exponent. In other words, to make the function fit the data, the proponents of the Phi-law subtract a constant physical intensity from the physical scale. But another possibility, called the Psi-law by Fagot and Stewart, is to subtract a constant magnitude from the psychological scale. It is not easy to directly compare goodness of fit of these two laws. But Fagot and Stewart, by making a reasonable set of assumptions, compare both versions against a number of criteria. In terms of a standard goodness-of-fit test, for example, the Psi-law does better than the Phi-law. On the other hand, the exponent changes with changes in size of the standard much more for Psi-law than for the phi-law.

A more crucial test is how estimates of the threshold change with changes in the size of the standard being compared. Here the Psi-law comes out as unequivocably superior to the Phi-law. In fact, the Phi-law leads to estimates of the threshold that are for the most part negative and out of line with what would be reasonable for a human brightness scale.

But even the apparent failure of the Psi-law to show a constant exponent with changes in standard may not be evidence against its conformity to data. It turns out that the exponent for the Psi-law shows a sharp change (drop) only in region from 0.1 to 0.3 foot-lamberts (this is true for all 9 subjects).

This region coincides with the level of intensity at which there is a switch from scotopic to photopic vision. In the region of photopic vision, the Psi-law seems clearly superior and in reasonable agreement with the data. On the other hand, the Phi-law seems to fit better for the low standards in the region of scotopic vision. This suggests the intriguing hypothesis, which Fagot plans to pursue further, that two different coding systems may be operating along the brightness continuum. What has up to now been treated as one phenomenologically unitary "dimension" of brightness may, upon the application of these new and more powerful criteria, decompose into two qualitatively different coding systems. Of course, we have long known that the brightness continuum is mediated by two different physiological systems. But this is the first time that evidence from psychophysical judgments has suggested a corresponding difference in terms of subtle features of the coding process. And this in turn, raises a question that will concern us more and more in our study of coding systems. Just what, in fact, are we to mean by a psychological dimension?

A copy of this study is also enclosed with this report.

In a third study in this series, Fagot and Stewart have focused their high powered analytic tools upon still another hallowed psychophysical method, the method of bisection. An implicit, but rarely tested, assumption underlying this method is the bisymmetry axiom. We can illustrate the axiom as follows. Let us ask an observer to pick a stimulus S3 such that S3 appears psychologically half-way between S1 and S5. Now we present the same observer with S1 and S3 and ask him to pick S2 so that it appears halfway between S1 and S3. We also ask him to pick S4 so that it lies halfway between S3 and S5. The result of these bisections is to produce a series of stimulus values S1, S2, S3, S4, and S5 such that S3 is supposedly halfway between the ends and S2 and S3 are halfway between the middle and their respective ends. If we now present our observer with S2 and S4, the bisymmetry axiom demands that he should pick S'3 such that it equals S3.

In fact, the observers do not do this. Instead, the last choice shows a systematic bias such that S'3 tends to be too high in comparison with S3. This bias suggests a spatial error in which the left hand stimulus is systematically overevaluated.

This finding raises at least two possibilities. One is to find ways to remove or compensate for this bias empirically. The other is to explicitly introduce a bias parameter into the measurement model. Either way, the finding suggests again that we can find ways of extracting measurements from subjective reports that are meaningful.

A report of this study is in preparation and should be ready for the next report.

2.2. Multidimensional Psychophysics

Hyman and Well (1967) have used the designations multidimensional psycho-physics and multidimensional scaling to differentiate two methods of examining judgments of multidimensional objects. In the scaling approach, such as

described by Torgerson (1958), the investigator assumes a known geometric model and then finds the number and direction of the dimensions that best describe the psychological judgments within the given geometric space. Until the recent development of non-metric procedures, this geometric space has always been Euclidean. In the psychophysical approach, on the other hand, the investigator assumes he knows the dimensions that are being used and tries to discover how the observer combines these dimensions; that is, into what type of geometric space can he embed his judgments?

Attneave, who first used the psychophysical approach (1950), concluded that observers combine the information from two separate dimensions in an additive fashion. Such a combinatorial rule leads to a geometric model that has since been designated the "city block space." Torgerson (1952) using the first clearly formulated multidimensional scaling procedure, concluded that the Euclidean combining rule appropriately described the similarity judgments of his subjects. Not only had Attneave and Torgerson used different approaches, but they had also used different types of stimulus objects--parallelograms varying in tilt and height by Attneave and red color patches varying in brightness and saturation by Torgerson.

Hyman and Well (1967) employed a combination of the two approaches as well as new criteria and concluded that the city block model does indeed describe how subjects combine information from geometric stimuli that vary in two perceptually distinct dimensions. Furthermore, the Euclidean model is the better one for describing the similarity judgments among color patches. In a subsequent study, Hyman and Well (1968) demonstrated that judgments of similarity of the color patches become better described by the city block model when variations on the two component dimensions are made perceptually distinct.

These results raise a number of questions in our quest to understand both judgments of similarity and how multiple inputs are coded. Do we in fact have two qualitatively different coding systems for judging similarity of multidimensional stimuli--one appropriate for color spaces and the other appropriate for spaces in which the dimensions are perceptually distinct? Or does the apparent fit of the Euclidean model represent an artifact due to a partial corruption of the application of an additive coding system? This latter possibility suggests itself on a number of grounds based on internal analyses of the data. On the other hand, there are other reasons, both introspective and theoretical, for believing that we are indeed dealing with two distinct levels of processing--one which is parallel and relatively more perceptual (the Euclidean) and one which is sequential and relatively more cognitive (judgmental).

Hyman and Well have partially completed a study which examines these possibilities further. In this new study, observers alternatively make judgments of similarity between pairs of stimuli and then are required to make discriminations between pairs that are identical and pairs that are different. The reaction time to classify a pair of stimuli as "different" is then compared with the actual judged magnitude of this difference. One goal of this study was to examine the relationship between discrimination latency and judged similarity. This relationship could form an important link

between various parts of the current project since, outside of the psycho-
physical area, our major dependent variable is latency.

A second goal was to see if the relationship between judged similarity
and discrimination latency would be different for stimulus objects that
obeyed the Euclidean model and those that obeyed the city block model. This
difference in relations would be predicted from the possibility suggested by
Torgerson (1965) among others, that similarity between colors is mediated by a
perceptual process that operates in parallel while similarity between geometric
stimuli is mediated by a process that operates sequentially upon the information
from each dimension.

The preliminary analyses show, as expected, that the stimuli judged
as more similar are more difficult to discriminate. Even more suggestive
is the fact that the slope of the straight line relating discrimination
latency to color similarity is much steeper than the slope of the line
relating latency to geometric similarity. This would be expected if, for
example, the judgment of difference between two color patches simultaneously
used all the perceptual information while that between two geometric stimuli
was based on the difference on only the most prominent and first-processed
dimension.

A stronger basis for such a conclusion may come when we apply the new
nonmetric multidimensional scaling procedures to our data. The advantage of
these methods is that they require only ordinal data about the relative
distances between pairs of stimuli. Under certain constraints, such procedures
can recover a ratio metric for the distances as well as decide between the
optimal form of the geometric model. We have recently developed and debugged
a program for such a method. We have applied it to our earlier data (Hyman and
Well, 1967) with encouraging results in that the nonmetric procedure classified
sets of judgments as "city block", "Euclidean", or otherwise in agreement with
our original classifications of the same data based on metric assumptions.
Another encouraging side-benefit is that the recovered distances agreed with
the judged similarities to such an extent that it again seems to confirm our
belief that subjects can make such similarity judgments according to a ratio
scale. This, in another way, is consistent with Fagot and Stewart's findings
with respect to the additive axiom for difference judgments.

Having confirmed the applicability of the nonmetric program to our judg-
ment data, we are now applying it to the discrimination latencies and the
similarity judgments of our new experiment. In this latter case the nonmetric
program enables us to create a metric and find an appropriate space for the
latency data, provided we can assume that time to discriminate between two
stimuli increases with their similarity. We can then match the spaces yielded
by these forms of response to pairs of stimuli. In the case of color patches,
for example, we are predicting that the two spaces, one based on judgments of
similarity and the other based on time to discriminate, will be the same form.
But in the case of the geometric stimuli we are predicting that the two spaces
will be qualitatively different--the judgments will yield the expected city
block space, but the latencies should yield a metric space that we have
previously labeled "dominance" (Hyman and Well, 1967).

If these expectations about the applicability of the geometrical models
to judgments and discriminations of multidimensional stimuli are fulfilled,
then we believe that we can add another powerful conceptual and methodological
tool to our repertoire for studying different aspects of coding systems and
the coordinate systems within which they can be embedded. Hyman and Well
are already working out the conceptual and methodological machinery to apply
these models to our work in selective attention. In this case the amount
and the form of interference of an irrelevant dimension can be examined on
the basis of how it combines with the relevant dimension to yield a geometric
space. For example, the geometric model that we have called the "dominance
model" becomes a good fit to judgments and/or discriminations whenever the
observer has trouble ignoring an irrelevant variable when its magnitude
is large relative to the relevant variable. Such a mode of interference
seems to be in accord with some of the data that Hyman and Well have collected
and which will be described in the next section on Attention.

Hyman is working out other theoretical analogs for each of the various
Minkowski power metrics which characterize the set of geometric spaces that
range between city block through Euclidean until the dominance model. For
example, the Euclidean metric with its lack of preferred orientation of
its dimensions (rotation invariance) seems to represent an ideal description of
a stimulus-generalization surface as implied by early models of S-R psychology.
Both the types of deviations from the Euclidean metric represented by the
city block and the dominance models stand for important qualifications or changes
that had to be made in the SR model to account for the fact that some attributes
were more salient than others and that powerful processes of selection occur
in learning situations.

The results of some of the applications of these models should be ready
for the next report.

2.3. Spatial coordinates and perceptual economics

Vernon (1952) has expressed a viewpoint about the nature of perception that,
from time to time and in different ways, has been suggested by many student.
of perception. "It may be generally stated that perceptual reconstruction
of the external environment always appears to aim at preserving the continuity
and stability of objects in the field. Moreover, it seems that continuity
of sensory experience is essential even for the correct interpretation of
that experience in terms of objects perceived." One of the necessary con-
ditions for achieving this continuity and stability of objects is the existence
of a visual frame of reference. When this visual frame of reference is
weakened, as in the autokinetic effect, position constance is disrupted and
a variety of perceptual disturbances occur (Beck, 1969; Kolers, 1968).

Attneave and his colleagues are conducting a series of studies on various
factors that influence the perception of orientation and depth in space. One
goal of this research is a psychophysics of geography or space. This would
be concerned with how the individual represents himself and other objects
with respect to spatial location. Another aspect of this research is how
internal representations of three-dimensional spatial coordinates are used in
the perception of two-dimensional figures. Many line drawings and some
illusions, for example, seem to be perceived "in depth." And the actual

interpretation or perceptual identification of objects seems to depend
heavily upon how the object is related to an internal set of spatial coor-
dinates. Still another ramification of such internal coordinate systems
is their ability to help the individual deal with various types of
cognitive and mnenomic problems. Many verbal problems become easy to "see"
or solve once they are translated or encoded into a spatial representation.
And some mnemonic systems explicitly depend upon ordering a set of unrelated
objects by arranging them mentally within an imaged spatial model.

A distinction should also be made between the spatial models being
investigated by Attneave and the geometric models of similarity being
studied by Hyman and Well (1967, 1968). These latter models are also called
"spatial models" and this has unfortunately led to some confusions. (for
example, the journal, Perception and Psychophysics, consistently and erron-
eously indexes the articles by Hyman and Well under "space perception".) On
the other hand, such a confusion, in the long run, may be a happy accident
The possibility grows, as our understanding of how individuals perceive
objects and their similarities increases, that the spatial models and
coordinate systems being investigated by Attneave are the prototypes out
of which the individual constructs general coordinate systems for perceiving
and identifying objects in general.

The intimate relationship between internalized representations of
spatial orientation and the perception of two dimensional form has been
strikingly demonstrated in two earlier studies by Attneave and his coworke-
(Attneave and Olson, 1967; Attneave and Reid, 1968). Using discrimination
latencies, these studies confirmed the belief that the human perceptual system
is much more sensitive to horizontal and vertical orientations than it is
to oblique orientations. However, the studies discourage the temptation to
think of these differential sensitivities in terms of built-in analyzers such
as have been found at the physiological level for frogs and cats. Instead,
the studies convincingly demonstrate that this preferred status for the hori-
zontal-vertical depends upon the phenomenal (perceived) vertical axis with
respect to the retina.

In a recently published paper on triangles as ambiguous figures (Attneave,
1968), Attneave again presents convincing evidence about the importance of
the phenomenonal vertical and the spatial frameowrk within which the object
is perceived. Both the orientation of triangles and their form, equilateral
or not, are influenced by a perceived orientation of the axis of symmetry
and whether the triangle is seen as in the plane of the two-dimensional
surface or as appearing on a plane tilted in depth. The results of such
perceptual achievements strongly suggest a minimum-complexity principle. The
perceptual system tends to see plane figures as so oriented, in terms of a
local vertical and in terms of apparent three-dimensions, to make the picture
consistent with a perspective view of a symmetrical object.

These findings suggest a coding or descriptive framework that resemble,
a Cartesian co-ordinate system. This coordinate system acts as a "schema"
for "intepreting" plane figures in such a way as to achieve the simplest
possible "description" of perceived objects. In the case of the perception
of triangles, two reference processes can be identified. One leads to a

description of the figure in terms of local axes embedded within a more general repr entation of a three-dimensional space. The other leads to a descriptior the tilt of these local axes from the axes of the more general space. These conclusions are, of course, in line with Attneave's conception of the perceptual system as a process of enconomical description (Attneave, 1954).

Attneave and Frost (1969) have recently completed a study that looks at still another application of the minimum principle in the perception of form. This particular study employs a new apparatus and psychophysical procedure to objectively measure the perceived tri-dimensionality of a plane figure. The observer views a line drawing of a "box". The box is projected to just one eye; at the same time, both eyes see a rod which is free to rotate in depth. The two visual fields are superimposed such that the rod is seen as continuation of one edge of the drawings of the box. The subject's task is to align the stick with the edge of the box such that the stick appears to be a collinear extension of the edge in an apparent tridimensional space.

Three different types of drawings of a box were employed. In condition I, all the lines representing the edges of the box were of equal length the plane of the picture. (This type of projection is called an orthogonal projection.) The three dimensional projection of such a box cannot, in fact, have its corresponding sides equal. To see such a box as three dimensional would involve seeing the sides the their slopes as unequal. On the other hand, only a tridimensional interpretation of the drawing would make all the corresponding angles equal. Thus, condition I pits cues of slope and length against the criterion of equal angles. The first two criteria, on the hypothesis of minimal complexity, would tend to keep the perceived figure as flat, while the third would tend to pull it into three dimensions. In a like manner, in condition II both angle and length criteria are pitted against the slope criterion, the latter tending to hold the representation flat. In condition III all three criteria, by hypothesis, are working to produce a tridimensional encoding of the perceived figure (this last condition corresponds to a box in linear perspective).

The results were amazingly consistent. Even in the condition with two criteria for flatness pitted against one for depth, observers consistently saw the "box" as tridimensional. Nor did their settings indicate any alternative of perception (the correlation between setting and calculated slope on the basis of equal angles was .97). Instead, the results indicate a "compromise" among the conflicting criteria. With one criterion for and two against depth, the slope was only .34. With two in favor of depth, the slope increases to .59, and with all three criteria pulling the perceived figure into depth, the slope increases slightly more to .63.

Among the remaining questions is why the slope does not reach 1.00 (which represents perfect agreement with the theoretical tridimensionality of the box if it were actually projected from a real object). Another question is why the contribution of linear perspective was relatively so weak. Attneave and Frost have conducted two further experiments to examine these second two questions. The results are now being written up.

A copy of the first experiment, which has been submitted to <u>Perception</u> <u>and</u> <u>Psychophysics</u>, in enclosed.

But the most important question is the extent to which the data can be interpreted in terms of an explanation used for understanding the perception of triangles and spatial orientation. The explanation, in that model, would be that subjects are perceiving the boxes in such a way as to minimize or simplify the relationships of the perceived figure with an internalized coordinate system. This is contrasted with a model that says that the perceptual system is perceiving the boxes so as to minimize disparity among its internal relationships--angles, lengths, slopes of lines. To separate the role of these two possibilities Attneave is currently trying to devise figures other than parallelopipeds that can be used within the frame work of the present paradigm. At any rate, it does seem clear that the perceptual apparatus does operate to minimize complexity.

3. ATTENTION

Coding processes imply attention. To direct attention to some part of the stimulus input is to devote processing capacity to that part at the expense of other parts (cf. Neisser, 1967). In this sense all our studies on coding behavior are studies of attention. However, the studies in this section, with one exception, deliberately ask the subject to "attend" to only a designated part of the stimulus input (the "attended message") and to ignore the remaining part (the "unattended message"). Such a task can be contrasted with the task requirements in the preceding section. When subjects were asked to compare two color patches for similarity it was assumed that they would do so on the basis of all the information available in the patches, i.e., on the basis of their differences in both saturation and brightness. When the subject is required or expected to use all of the available stimulus input in making his response, we refer to the task as one of either information conservation or information condensation (Posner, 1964). When the response preserves all of the information in the input, we call the task one of conservation. When the response is based upon all of the information, but does not preserve it, we call the task one of <u>condensation.</u>

When the task requires that the subject deliberately ignore some of the input we call the task one of "gating" or "filtering." One of the issues in such studies is the degree to which the subject can actually achieve such filtering. This issue, in turn, contains several sub-issues. To what extent does the unattended message <u>interact</u> with the attended message? Such interaction can manifest itself in the form of either facilitation or interference with the processing of the attended message.

The preceding question focused on the efficiency in processing the attended message. One can also ask about the fate of the unattended message. It is blocked or filtered at the periphery? Is it processed along with the attended message? Still other issues have to do with the criteria that the perceptual system uses to separate input into separate "channels" or parts; do both the unattended and attended message compete for "space" in the same central processing system or are we dealing with several relatively independent channels among which a central process can allocate portions of its "attention"?

3.1. Dichotic listening

Lewis is preparing a paper which summarises his first two experiments on the semantic processing of unattended messages in dichotic listening. In these experiments the subject receives sequences of unrelated words in one ear. These occur at the rate of one word every two-thirds of a second The subject's task is to "shadow" these words; that is, he has to repeat each one aloud as soon as it occurs. At this rate of shadowing an "attended message" the subject cannot recall or report anything about the content of a word that is simultaneously presented to the unattended ear.

Lewis wanted to know if any aspects of the unattended word are processed or have a detectable effect, even though the subject cannot recall anything specific about the word. To get a sensitive measure of the possible effects of the unattended word, Lewis observed how the time to say the attended word varied as a function of the relationship between the attended word and the unattended word. In both studies he found that when the unattended word is synonymous with the attended word that is occuring simultaneously, the subject's time to say the attended word is significantly lengthened.

This interference effect of synonyms was not exhibited by unattended words that were "high associates" to their attended pair mates. A post hoc analysis revealed that high associate words contain many antonyms, and unlike synonyms, antonyms seem to facilitate response to the attended message. This outcome would seem to have implications for studies in verbal behavior an meaning which use indices of association as a measure of "meaning". More importantly, in terms of theories of selective attention, Lewis' findings suggest that filtering of the unattended message does not take place peripherally, but that at least some higher order aspects of the unattended message reach or affect the same central processing mechanism that is dealing with the attended message.
Copies of this paper should be ready for the next report.

Reicher and Snyder have just completed a study on dichotic listening and the results are still being analyzed. The question of interest was what kinds of factors make it difficult or easy to ignore information in the unattended ear. The subjects shadowed a string of random letters that were presented, one at a time to the attended ear. When the input to the unattended ear consisted of letters that repeated themselves, the subjects made approximately 18% errors in shadowing the letters. When the sequence of unattended letters were different but in alphabetical sequence, the errors in shadowing the attended message increased to approximately 28%. Finally, when the letters to the unattended ear were in random order, the errors in shadowing increased to over 31%. A control series was also run using repeated numbers, numbers in sequence, and numbers in random order in the unattended ear. The statistical analysis is not completed, but it is clear that random numbers interfere with the shadowing of letters much less than random letters.

These results, in conjunction with those of Lewis, again bring into question the notion that the unattended message is only processed at what Neisser calls a "preattentive level" (Neisser, 1967) or that the unattended

message is attenuated to such an extent that only crude global properties reach the central processing system. Reicher's results strongly suggest that the subject has to sufficiently process what is coming into the unattended ea to extract information about repetitions and sequential dependencies. To ignore a sequence of letters that has no sequential dependencies apparently requires more processing capacity, as indicated by the interference with the shadowing task, than it does to ignore a more structured input. This, in turn, suggests that ignoring information may involve an active inhibitory process that employs processing capacity; the more complex or unstructured the information that has to be ignored, the less capacity the subject has for the attended message.

Much of the work on selective attention is based on a working model that assumes that the subject can attend to a single "channel" at a time When, as it sometimes happens in dichotic listening experiments, the subject suddenly becomes aware of a word or phrase occuring in his unattended ear, it is usually assumed that he momentarily switched his attention to the unattended ear. Indeed, many attempts have been made to measure the amount of time it presumably takes to switch from one channel to another. Lewis has recently completed the first part of a study to obtain a reasonable estimate of such switching time. The subject received a constant white noise in the attended ear. At the onset of a tone, the subject had to press a key to classify the tone as "high" or "low". Sometimes the tone appeared in the attended ear and sometimes it appeared in the unattended ear. To make sure that the subject did attend to the white noise in the attended ear, the white noise was turned off occasionally before the onset of the tone. Under such conditions the subject was instructed not to respond. With such a paradigm, Lewis was able to estimate that it takes the subject somewhere between 20 and 40 milliseconds to switch attention from one ear to the other. This estimate, of course, may apply only for simple stimuli such as tones.

3.2. Simultaneous audio-visual presentation

Lewis completed a study similar to his one on semantic processing in dichotic listening. But in this case the attended message was either presented auditorily or visually; the unattended message was presented to the ears for the case of a visually attended message and to the eyes for an auditory message. As in the preceding study, the subject "shadowed" the words in the attended message at a rate of approximately one every two-thirds of a second. Every fifth word in the attended message was accompanied by the simultaneous presentation of a word in the unattended modality.

In one aspect, the experiment failed to replicate the dichotic listening situation. The rate of shadowing of the attended message was sufficiently demanding in the dichotic listening situation that on test trials, the subject was never able to report the word that had just been presented in the unattended ear. The recall of the unattended message was essentially zero. At the same shadowing rate in the present experiment, however, the subjects had no difficulty whatsoever in recalling the word that was presented to the unattended modality. In this respect at least the simultaneous input to eyes and ear is relatively independent in comparison to the simultaneous input to two ears.

However, the question can still be meaningfully asked about the relative interference of what is presented to the unattended modality upon the shadowing of the words in the attended modality. In this respect, the effect of synonyms presented visually when the auditory message is being shadowed appears to be similar to that in the dichotic listening experiment (that is, a synonym appearing on the TV screen seems to slow down the subject's time to call out the word he simultaneously hears on the earphones). The reverse effect, however, did not occur. That is, when the auditory message was unattended, a synonym did not impair the speed of naming a visually presented word. There was some evidence, however, that the visual shadowing was facilitated when the auditory message was a word that made a sequence with the visual word (e.g., "street" "car"; "get" "lost").

There were many complicated interactions associated with this experiment. For example, the effects were somewhat different when the auditory message came from the speaker of the same television set that presented the visual message than when the auditory message came by way of earphones. In addition, it would be desirable to replicate the experiment under conditions where the unattended message was not so clearly perceived. To overcome many of the technical difficulties involved in such an audio-visual study, Lewis has been working out the necessary technology to conduct his study with the aid of the PDP-9 computer.

3.3. Visual-visual tasks

Hyman and Well have completed a study as a part of their series on the role of perceptual separability in perception of similarities and differences among multidimensional stimuli. In the section on psychophysics, we described a task in which the subjects were required to classify pairs of color patches or geometric forms as "same" or "different" on the basis of perceived differences on any or all dimensions. The object was to see how subjects combined information from two color dimensions, which are not perceptually separable, in contrast with how they combined information from two formal dimensions such as size and slope, which are perceptually separable. In a parallel study, the subjects were required to classify a pair of colors as same or different only with respect to one of the two dimensions on which they could differ. We wanted to see how easy it was to ignore the "irrelevant" dimension for the two kinds of stimulus materials--color patches whose similarities usually follow the Euclidean model and geometric shapes whose similarities usually follow the city block model.

In addition, we wanted to study the ease or difficulty of ignoring the irrelevant dimension as a function of the relative discriminability of the attended dimension with respect to the unattended dimension. For a variety of reasons, Hyman and Well were entertaining the possibility that this relation of filterability to discriminability would differ for color patches and the geometric forms (circles-with-radius).

As would be expected, the task of ignoring the irrelevant dimension is much more difficult in the case of color patches that vary in brightness and saturation that it is in the case of circles that vary in diameter and slope of their radii. The subjects make many errors in classifying the colors;

they make very few in classifying the circles. This makes the classification time much easier to interpret for the circles.

For the color patches, the time to recognize two patches as having the same saturation is markedly slowed down by even a small difference in brightness (from .7 seconds to 1.1 seconds). The same is true for recognizing two patches as having the same brightness when there is even a small difference in saturation (from 0.6 seconds to 0.9 seconds). Surprisingly, to detect two color patches as "different" there is no facilitation of effect of differences on the irrelevant dimension. That is, when two color patches differ at all on "saturation", increasing the magnitude of difference on the unattended dimension of brightness from 0 to 4 steps on the Munsell scale has no effect on the discrimination time.

For the circles, the time to classify a pair of circles as the "same" on the basis of the relevant dimension is slowed down only for rather large differences on the unattended dimension. As expected, then, the subjects have found it somewhat easier to ignore the irrelevant dimension when it is perceptually distinct, but they cannot ignore it completely, especially when the differences are large. On the other hand, when two circles differ only slightly in size, the discrimination time seems to be facilitated by a large difference in angle. However, there seems to be no facilitation of recognizing a difference in angles when there are simultaneous differences in size.

These results are consistent with a competition of response interpretation of interference effects (Egeth, 1967). Large differences on the irrelevant dimension can interfere with classifying two circles as the same, but can facilitate classifying two circles as different. But these interactions seem to happen only at the extremes. For the most part, the subjects seem to do a reasonable job of filtering out the irrelevant dimension for these stimulus objects. Hyman and Well plan to further analyze these data by means of the nonmetric scaling program discussed under multidimensional psychophysics.

Well has developed the program on the PDP-9 for investigating various factors that facilitate and impede selective attention in an experimental paradigm based upon the card-sorting experiment of Imai and Garner (1965). He has finished the first three experiments in a series of experiments which will be included in his doctoral dissertation.

The object of the thesis is to isolate various factors such as competition of responses, discriminability, prior training, and opportunity to preview the next stimulus which possibly play a role in the efficiency with which individuals can "gate" out irrelevant information. The Imai and Garner (1965) experiment was chosen as a starting point because, according to Egeth (1967), it is the one major exception in a series of speeded classification tasks that demonstrate that subjects cannot completely ignore dimensions that have previously been relevant. "In view of the fairly strong evidence supporting the competing-response hypothesis, it seems somewhat surprising that Imai and Garner were able to demonstrate perfect filtering since, for their subjects any given stimulus dimension was relevant in some conditions and irrelevant in others."

This "perfect filtering" that Imai and Garner demonstrated occurred in
a card sorting task of the following kind. On each card were two black dots.
The dots could vary from one card to the next in terms of distance (D); in terms
of position on the card(P); and in terms of orientation (whether the top
dot was to the left or right of the bottom dot) (O). On a given trial the
subject was told to sort the deck into two piles according to values on just
one of the dimensions. For example, if D was relevant for that trial, the
subject would put the cards in which the distance was larger in the left
pile and those for which it was smaller in the right pile. The dependent
variable was the time it took the subject to completely sort through a given
deck on a trial. The time to sort through the deck on the basis of D was
compared for conditions where the other two dimensions did not vary, where
one of the other dimensions varied, and where both of the other dimensions
varied. Imai and Garner found that, on the average, it took no longer to sort
through a pack on the basis of a given dimension when the other two dimensions
did not vary than when one or both irrelevant variables varied.

Egeth finds this puzzling because in this situation the competing response
hypothesis would predict slower times when the other dimensions varied.
When a subject is deciding whether to put the card with a large distance into the left pile, the fact that the dots are in the right position, which
previously was a relevant cue for the right pile, should tend to impede
his placement. Egeth offers two possible explanations. The first involves
the fact that the subjects held the deck face up when making their sorts
and thus could preview the next card while executing the motor movement for
placing the card already classified in its proper pile. In addition, even
when an irrelevant dimension remained at a fixed value it still could arouse
competing response tendencies.

To these possibilities suggested by Egeth, Well adds two more. Imai
and Garner had previously used the same subjects in an extensive series of
classification tasks with the same cards. This long series of other tasks
with these stimuli maight have built up enough "predifferentiation" to make
it subsequently easy to perceptually separate the different dimensions.
And another possibility is simply that a card sorting task is simply too
insensitive to demonstrate interference among competing dimensions.

In Well's computer-aided experiment, the stimuli are generated by the
computer and displayed on a cathode screen on each trial. The subject make'
his classification, according to the relevant dimension for that series by
pressing one of two keys. In this way latency is recorded for each classi
fication rather than for the entire sorting of a series. In the first three
experiments the subjects were given no preview. Experiment I was otherwise
similar to the Imai and Garner experiment in that each dimension was, at some
time in the experiment, relevant. If Egeth is correct this represents a
situation where competing responses should build up and prevent perfec,
filtering. After three days experience on this task, the data revealed
interference from irrelevant dimensions when Distance or Orientation was
relevant. The data suggest that when Position was relevant, filtering wa
essentially perfect.

Experiment II was essentially a replication of the first experiment, except that the discrimination on position was made somewhat more difficult. In this case, interference was obtained on all three dimensions. Three of the subjects of Experiment II were run an extra two days. This still did not remove the interference effects although there was some suggestion that they might be disappearing when the discrimination on the relevant dimension was especially easy.

In Experiment III, 9 subjects were run for three days under conditions where only one dimension was ever relevant for any given subject. Such a condition, should minimize the competition of responses between dimensions. The results are unclear, but they strongly suggest that, at least for easy discriminations on the relevant dimension, interference by the irrelevant dimensions is essentially zero. However, when the discrimination on the relevant dimension is difficult, the variations on irrelevant dimensions still interfere. This result complements that of Reicher and Snyder, which implicated the processing capacity needed to filter out the irrelevant dimension. In this case, when the relevant dimension demands more attention, presumably the subjects ability to ignore the irrelevant dimension is impaired.

Well plans to conduct a few more experiments to examine the role of practice independently of competition and to see if preview can remove interference. His thesis should be finished in time for the next report.

3.4. Detection of location versus detection of identity

In his Master's Thesis, which is almost completed, Snyder presented words of 7 letters at exposures of less than 100 msecs. The subject's task was to indicate the position in the word that contained a mutilated letter (say an N with a missing bar). After he indicated the position (say, the fifth letter), he was also asked to name the letter that was identified. These two tasks, naming the letter and locating its position in the word were counterbalanced in terms of the order in which they were performed on any given trial. The surprising finding was that detecting where the mutilated letter is seems to be a process that is carried out independently of identifying what the letter is. Sometimes the position estimate was in error but the letter name was correct and vice versa. When position was correctly identified, the letter that was named was not the mutilated letter but one that was adjacent to or near it in the array.

Snyder suggests that the subjects carry out a two part strategy. They first establish the relative position of the mutilated letter by a fast, preattentive process (Neisser, 1967), and then scan the internalized image of the array by a serial, higher level process to identify the name of the letter. He is now conducting a series of further experiments with different types of array. The results seem to fit in with recent psysiological findings that suggest that the physiological mechanisms for determining what an organism sees are different from those for determining where he sees it (Ingle, Schneider, Trevarthen, & Held, 1967). The results are also in accord with our findings to be described in the next section.

4. MATCHING TIME AND LEVELS OF PROCESSING

The experiments in this section are all based on simple, but powerful experimental paradigm developed by Posner for the study and isolation of different levels of coding behavior (Posner & Mitchell, 1967). This paradigm was developed as a sophisticated application of Donder's subtractive method to the analysis of depth of processing in classification tasks. The stimuli are always pairs of items (letters, nonsense forms, digits) to which the subject has to respond "same" or "different" as quickly as possible. Different "levels" of processing are compared by changing the instructions about the basis for classifying two objects as the "same". In the early applications of this paradigm the levels of instruction were physical identity, name identity, and rule identity.

If the stimuli to be matched are pairs of letters, for example, only the first pair in the series AA, Aa, Bb, AE, AV, would be classified as the "same" by physical identity instructions. For a series that was based on name identity, however, any one of the first three pairs would be classified as "same" and the other two pairs would be classified as "different". At the level of rule identity, say, all pairs that are both vowels or both consonants would be classified as "same"' by such a rule all but the last pair would be classified as "same". In the early series of experiments, for example, it was discovered that a physical match was consistently 70 milliseconds faster than a corresponding name match. These experiments further established that physical identity matches take place before the actual letters involved in the match are identified.

Since then the matching paradigm has proved to be a powerful tool in isolating the nature of the coding systems that take place at different levels of processing such as in visual coding, name coding, and supraordinate classification. By adding successive rather than simultaneous presentation of the two items to be compared, Posner and his associates have provided much useful information about how the visual code becomes converted into an acoustic or articulatory code, how visual codes can be regenerated from symbolic codes, how perceptual information interacts with stored representations or "abstract ideas", and how different types of representation obey different laws of retention and forgetting. One of the most striking applications of this technique was to separately manipulate the name and visual codes for a given letter. Many of these experiments are summarized in the recently published monograph by Posner and associates, "Retention of visual and name codes of single letters" (Posner, Boies, Eichelman, & Taylor, 1969). Reprints are enclosed.

In his chapter on "Abstraction and the process of recognition" (Posner, 1969) Posner not only reviews the results using this matching paradigm, but integrates them into a theoretical context which also includes the experiments to be discussed under the next section on pattern recognition. The theoretical integration focuses upon the processes that might be involved in a task such as recognizing a handwritten letter as an "A". At the first level of processing, the stimulus input from the letter is registered as a set of lines which form a unified but unfamiliar figure. As the stimulus input is further processed it is brought into contact with past experience.

The partially processed input is compared with and finally matched with a trace system that Posner calls an "abstract idea". This abstract idea corresponds somewhat to what Hebb would call a cell assembly; it represents a primative classification or crude recognition of the input. This abstract idea is in turn connected with the name of the letter when the pattern is indeed one that has previously been connected with a name. The next stage would represent a classification of the name or the abstract idea into one or more supraordinate categories.

This model processing is not meant to imply that these levels must occur in a serial order. In fact, one of Posner's current projects is to identify conditions under which the processing of a letter or word can bypass the name level on its way to a supraordinate classification. Under what conditions, for example, can we classify a letter as a vowel or a word as a noun, say, without first identifying the actual letter or the actual word? And other experiments in our laboratory such as those of Lewis on semantic processing of unattended messages are closely concerned with the possibility of skipping directly from something like the abstract idea to the meaning of a word.

As information proceeds though these various levels it becomes more and more abstract in at least two senses. It loses, or can lose, many of the original details contained in the perceived stimulus; and it becomes representative of broader and broader classes (in the sense that "animal" is more abstract than "dog" which, in turn, is more abstract than the particular dog who is now nipping at your heels, etc.). Posner refers to the process of classifying the input into higher levels as the process of "abstraction". But he also reviews the evidence from his researches that, in a sense, the process can be reversed some degree, as when the subject generates a visual image from the spoken version of a letter. This latter process is called "generation".

Further discussion and examples of this integrating schema can be found in the two articles cited. Copies of the chapter on abstraction and the process of recognition are also included with this report.

The earlier applications of the matching paradigm were applied to situations in which the paired items were single elements or units. For such units, letters for example, the evidence was fairly conclusive that familiarity had no effect upon the perceptual processes that take place at the level of physical matches. But evidence soon accumulated that familiarity and learning did have effects at the perceptual level in facilitating the integration of complex stimuli such as arrays of letters in the form of familiar and unfamiliar words, etc. Our visiting scholar, Dr. H. K. Beller has employed the matching paradigm using strings of letters to see if he could demonstrate that visual matches taking place at the physical identity level are achieved by way of processes that can be identified with what Neisser has called "preattentive processes" (1967). At this stage, the perceptual system makes crude global groupings and operates upon global features in a parallel manner. Matches that take place at the name identity level, on the other hand, should be achieved by processes that Neisser calls "focal attentive". Here the identification is achieved by processing one portion (letter or letter pair) of the stimulus array at a time.

In his first experiment, Beller employed strings of letters that could
be 2, 4, or 8 letters in length. The subject's task was always to respond to
such a letter string as "same" whenever all of the letters had the same name.
If we had sequences such as "AAAA", "AAaAaAAa", "AAABbbbb", for example, the
first two strings would be classified as "same" and the last one as "different".
Within this experiment, Beller could compare the effect of increasing the number
of letters upon the time to recognize strings of letters as the same when all
the letters were physically identical and when all the letters had the same
name, but were not physically identical.

The results tend to support Beller's presupposition that increasing the
string from 2 to 8 physically identical letters does not increase the time
to recognize it as "same". If we just look at the added time required to
recognize the letters as having the same name when they are not all physically
identical we find that this is 71 milliseconds for strings of two letters, a
finding which is strikingly in accord with Posner's earlier results. And
with eight letters this difference increases to 98 milliseconds, which supports
Beller's original contention. But the results for four letters do not fit
this pattern; for some unknown reason strings of four letters were more
difficult than either strings of two or eight.

When the reaction times for "different" are considered, the findings
indicate that strings in which all 4 or 8 letters differ from each other
are classified as different significantly faster than strings of two different
letters. Furthermore, reaction time is consistently   faster the more
different letters there are in a string. This finding clearly eliminates any
simple scanning model which assumes that subjects scan the letters until they
find the first one that differs from the rest. Instead, they imply that
somehow the time to discriminate a set of letters that has at least one
different letter depends upon the number of different letters. This would
imply, when taken in conjunction with the "same" responses, some sort of
sampling model which is based on total dissimilarity or discriminability
rather than a serial, self-terminating search process. The data are also
compatible with a competition of response model that states that reaction
time to "same" depends upon the number of elements in the array that are
evidence for a "same" response, and that time to detect "different" is slowed
down by the number of repeating letters in the stimulus.

To overcome some of the problems of the preceding experiment, Beller
did a new experiment with a slightly different design. This time the letter
strings were arranged so that to recognize a stimulus as "same" the subject
would be forced to identify corresponding letter pairs for name identity
matches. If such name identifications must occur in a serial fashion, then
the more such corresponding pairs the subject has to identify, the more time
should be required. As in the procedures employed by Sternberg (1967)
and Neisser and Beller (1965), one can estimate the time per letter pair for
naming, as compared with merely making a physical identification match. Some
typical arrangements of the stimuli in the present experiment would be as
follows:

```
AB    AB    ABCD    ABCD    A    ABCD
DB,   ab,   abcd,   EFGH,   B,   ABCD.
(1)   (2)   (3)     (4)     5)   (6)
```

In these examples, the subject would respond "same" to arrays 2, 3, and 6 and

"different" to the others. Arrays 2 and 3 would be examples of a name identity match while item 6 would represent a physical identity.

The results are not completely analyzed, but overall mean trends are quite interesting and stable. If we look at the "same" reaction times for one pair, two pair, and four pairs of letters to be compared, then we find that physical identity matches increase at a rate of 70 milliseconds per letter pair to be compared. This clearly indicates that for this situation the physical identity matches for corresponding letter pairs are being made in a serial fashion. If we compare this with the name identity matches in which every pair of letters to be matched involves an upper and lower case letter of the same name, we find that the name identity matches increase at a uniform rate of 165 milliseconds per comparison. Therefore, in this situation we can infer that name identity matches take over twice as long per comparison as do physical identity matches.

Additional information of interest comes from the rate of increase in time to classify two strings of letters as the "same" when one pair of corresponding letters always involves a name identity, but where each additional pair involves a physical identity match. Here, the addition of physical identity matches to a name identity match produces a systematic increase of 70 milliseconds per extra comparison. This strongly suggests that the two processes, physical matching and name matching, are additive processes that operate independently.

In his doctoral dissertation Johnson applied the matching paradigm to pairs of stimuli that consisted of a row of eight contiguous black and white squares. If the corresponding squares in two such stimuli were the same color, the subject was to respond by pressing the key indicating "same": if there was at least one pair of corresponding squares that were of different colors, then the response was "different". In earlier work with these stimuli, Johnson and Anderson discovered that they could predict 92% of the variance in the "same" reaction times by classifying the paired stimuli according to a "runs code". This code is based on the number of runs of black squares and the distance, i.e., the number of white squares, between runs.

The black squares within any run, no matter how many, were apparently processed simultaneously, but each run was compared serially between the stimuli until a mismatch, if any, was detected. Since the original study by Johnson and Anderson entailed a five-second interval between presentation of the first row of eight squares and its comparison, it is reasonable to conjecture that the matches were being made by some non-visual, possibly articulatory, coding. Johnson predicted, on the basis of the work of Posner and others, that if the pairs of stimuli were presented simultaneously, the match would be made according to the same process that occurs in a physical identity match. Essentially this process would be a parallel, analog type of match. With the introduction of the 5-second delay, however, he hypothesized that the abstract idea of the first stimulus would be encoded into a symbolic form (such as two runs of black squares with one white between). Hence the basis for the match after a delay would be qualitatively different. Simultaneous matches would be based upon analog (perceptual), relatively unprocessed input. Memory matches would be based upon a highly coded, digital and symbolic characterization of the stimulus.

Johnson included four different conditions and his analyses involve
many control comparisons. The results, in detail, are somewhat complex since
situations in which stimuli differed by 0 or 1 unit on the runs code behaved
differently from situations in which there was no condition with zero differ-
ence. But the overall findings can be interpreted as supporting Johnson's
hypothesis in a modified form. As an index of visual, physical identity
processing, Johnson used a measure of 'brightness". He pitted differences
between brightness and differences between "runs codes" against each other
at both zero and 5-second intervals between stimuli to be compared. In the
main, differences in brightness do predominate at the zero-second interval
and the runs-code does predominate at the 5-second interval. But there
is some evidence that the runs code, at least in a crude form, plays a role
at zero interval and that the brightness differences still have an effect at
5 seconds. It is possible that the measures of "runs code" and "brightness"
differences reflect only imperfectly the stimulus properties that the subject
is suing to make his discrimination. But, even if this is so, the data do
make it clear that subjects are doing something qualitatively different
when they match at zero-second intervals and at 5-second intervals.

Johnson considers a variety of models to account for this data. Some
can be rejected outright and others are more or less plausible. He concludes
that the results indicate that both brightness differences and runs-code
information are important determinants of latency of classification. The
information based on the runs-code is tested serially in a non-exhaustive
fashion until a discrepancy is found. Brightness information, on the other
hand, is tested in parallel; the larger differences in brightness resulting in
a more rapid discrimination and faster reaction times. Johnson further suggests
that these mechanisms operate independently and that the discrimination could
be made, on any comparison, on the basis of either one.

A copy of Johnson's dissertation is enclosed.

Taylor, in his doctoral dissertation, posed two questions: (1) "Given that
a visual stimulus can be responded to directly, as it is perceived at the
moment, or that it can be perceived, stored, recalled and acted upon later in
its absence, then do the recalled and perceived representations describe the
same stimulus with equal efficiency?"

(2) "And, since it is possible for either recalled or a perceived repre-
sentation of a stimulus to be acted upon, are there circumstances in which
they interact as sources of information?"

The experiment that Taylor used to get at these questions was a modifi-
cation of the matching paradigm. The subject looked into a tachistoscope onto
a field which had three "windows". A comparison stimulus could occur either
in the right or the left window. A target stimulus always occurred in the middle
window. On any trial, a typical sequence of events was as follows:

1) A comparison stimulus appeared in either the left or right window
and remained on for 0.5 seconds;
2) A masking field (a random checkerboard) followed and remained on for
3.0 seconds;

3) Finally a .nird field presented the target stimulus, always in the middle window, and a second comparison stimulus in either the right or left window. This test field remained on for 2.0 seconds.

In this sequence, the first comparison stimulus had to be stored in memory for the 3.0 seconds before the test field appeared. The second comparison item always appeared in the test field simultaneously with the target item. Thus, one comparison item was always in memory store when the target appeared and the other comparison item always appeared at the same time as the target.

The subject's task was always to press the switch indicating "same" when ever either the memory comparison or the simultaneous comparison item wa_ identical to the target. What was of interest, of course, was 'ne possible differences in reaction time when the memory item matched the target as compared to the situation in which the simultaneous comparison matched the target. The second question was concerned with what happens to matching time when both the memory item and the target item are identical.

Taylor examined these questions and their implications in a series of seven different experiments all based on the same paradigm. Within this paradigm, the memory matches were always consistently faster than the adjacent matches and this advantage increased with practice. Interestingly enough the same pattern of results held consistently for four different kinds of stimulus material: letters of the alphabet; nonsense figures; codable color patches; relatively uncodable color patches. This advantage for the memory matches persisted even in experiments in which subjects were run under conditions where they made only memory matches or only adjacent matches (to control for possible strategies that might favor the memory matches). Other experiments seemed to eliminate the possibility that the subject was storing the memory item as a "template" or iconic memory image; but they also seemed to eliminate the possibility that he was storing it in the form of a simple name or auditory code. Taylor proposes a possible model that assumes that with practice the subject develops economies in storing and representing the memory item. In a sense, he need only deal with the minimum amount of schematic detail sufficient to decide that this item was identical or not to the target. Such a schematic abstraction was not possible with the adjacent stimulus which had to be "read in" simultaneously with the target item.

Such a model, or something like it, may be plausible in this particular situation because the subject, on any block of trials, was faced with a total population of only three different stimulus objects. This restricted population might also explain the lack of effects, especially interactive ones, due to the nameability or form of the stimulus material. It will be important to see if this memory match advantage persists for situations where the stimulus population is much larger, or even is varied, from trial to trial. Under such circumstances we would also expect codeability or nameability effects to make their entrance. The question of population size becomes important when we note that in other applications of the matching paradigm, such as that of Johnson's, the match from memory is actually slower than the simultaneous match.

In Taylor's final experiment he included a variety of conditions which provide a useful summary of many of the interesting findings emerging from

his paradigm. In this last experiment there were conditions in which both comparison stimuli were identical to the target (symbolized by AAA), where only the first comparison stimulus was identical (symbolized by AAB), where only the second comparison was identical (BAA), where both comparison stimuli were identical but different from the target (BAB) and where the comparison stimuli were different from each other and from the target (BAC). Furthermore, there was a condition in which all the stimuli appeared simultaneously as well as the mixed condition in which the first comparison was in memory. The reaction times, averaged over six subjects in each condition, are summarized below:

Reaction Time for Correct Responses (Msec.)

Condition	AAB	BAA	AAA	BAB	BAC
MIXED	576	628	541	701	662
SIMULTANEOUS	602	584	588	687	659

The most interesting results in this table are for the situations when both the memory comparison and the adjacent comparison are the same (AAA and BAB in the Mixed Condition). Here we see that the reaction time to say "same" is apparently facilitated when the adjacent stimulus is the same as the stored comparison. This eliminates the most obvious model of why the memory match is faster (in that model we assume that the subject does not have to process the adjacent stimulus unless it does not match the target). Another unexpected finding is that the "different" reaction is markedly impaired when the memory and adjacent comparisons are the identical but differ from the target.

One possible clue to what is happening might be in the fact that "same" reactions are faster to the extent that all pairings of the three stimuli are identical. And different reactions are faster to the extent that all three pairings of the three stimuli are different. This is reminiscent of the competition hypotheses under selective attention and the "read-in" hypothesis of Eichelman's which will be described under the section on motor performance. Assume that the stored memory comparison, being the last stimulus processed, creates an advantage for reading in a stimulus that is identical or very similar to it (this seems to be like the stimulus repetition effect found by Eichleman). Under AAA condition, then, both the target and the adjacent comparison can be read in very fast and hence all evidence is in favor of the "same" response with no competing information. But under AAB, the target is read in fast and thus predisposes towards a fast "same" response, but the lack of a fast read-in for the adjacent stimulus provides some competing strength for a different response. Similarly for the BAB situation, the adjacent stimulus is read in fast and creates a tendency to react "same", but the slow read-in of the target counteracts this. In condition BAC, the lack of any immediate evidence for "same" enables the subject to quickly opt for "different".

A copy of Taylor's thesis is enclosed.

Posner is currently preparing a paper "On the relationship between letter names and superordinate categories." In this paper he cites convincing evidence that a subject first has to go through the name code (i.e., identify

the particular letter) before he can classify a letter as a vowel or con-
sonant. On the other hand, the subject can bypass the name code in order
to identify a symbol as a letter or a number.

5. PATTERN RECOGNITION

The basic paradigm for studies in this section is as follows. During an
acquisition stage the subject learns, by means of paired-associates, to classify
a set of "examples" or "exemplars" into two or more categories. Such classi-
fication learning differs from paired-associate learning in that there are
always more than one exemplar for each response or class name. In such a
many-one information reduction task the interest is in what has the subject
learned after he has mastered the correct labels. At one extreme, usually
called pure rote learning, the subject may have separately stored
each pairing of an exemplar with its class name. At the other extreme the
subject may have "abstracted" out a common "pattern" that enables him to
identify each example. If, indeed, the subject has abstracted out such a
pattern, then he ought to be able to "recognize" or correctly classify new
members of the class that he has not previously encountered.

This emphasis upon what the subject has stored dictates the second aspect
of the paradigm. Immediately after mastering the association of the correct
labels to the examples, or after some interval of time, the subject is tested
on transfer task. This test includes not only the examples he has previously
mastered, but also a number of new exemplars. By noting how he classifies
the new exemplars in relation to the old ones we can obtain a pattern of
generalization which often reveals important information about the nature of
the concept or pattern which the subject has acquired.

5.1. Abstraction of the prototype from dot patterns

The prototypical experiment upon which the work in this project builds
is described in the paper by Posner and Keele "On the genesis of abstract
ideas." (Posner & Keele, 1968). In that paper the stimuli were random dot
patterns which had previously been scaled for similarity (Posner, et al.,
1967). The subject learned to classify 12 dot patterns into three categories.
The correct classification depended upon the fact that each dot pattern was
a random distortion of one of three prototypical patterns. During acquisition,
the subject never was exposed to the prototype pattern. The pattern recognition
test included old distortions (the examples the subject had learned during
acquisition), new distortion of the same prototypes, and the prototypes them-
selves. Both errors and classification time during the transfer task indicated
that the prototype patterns were more easily classified than were the control
or new distortions. Posner and Keele argued that this result provided
convincing evidence that the subjects are capable of abstracting out infor-
mation about the prototype pattern,which had not been part of the original
learning process, with relatively high efficiency.

In terms of Attneave's (1954, 1959) ideas about economical encoding,
it is indeed efficient for a pattern recognition system to store a prototypical
pattern rather than the separate exemplars in order to recognize future members
of the class. However, in the first series of experiments the subjects also

did as well on the original exemplars as they did on the prototype. In terms of perceptual economics the storing of both the original exemplars and the prototype is markedly inefficient. In addition, this privileged status for the original exemplars, as Posner and Keele have pointed out, leave open the possibility of the subjects not actually learning the prototype during acquisition. Instead, one might argue that the subject stores only the individual exemplars during learning, but during the recognition task he "recognizes" the prototype as a particularly good example of the class pattern on the basis of its simultaneous similarity to the set of stored exemplars.

The possibility raised in the last paragraph can be rephrased in terms of when, in fact, does the subject abstract out the information about the central tendency of the class pattern. Does he perform this abstraction of the prototype during the learning of the individual exemplars: or does the superiority of the prototype over the new exemplars emerge only during the recognition task? In order to demonstrate that the prototype is abstracted from the stored instances, either during acquisition or during retention, it would be necessary to find conditions under which the prototype was recognized better than the original exemplars right at the beginning of the pattern recognition task.

Posner and Keele noted that Bartlett (1932) had suggested that forgetting will tend to affect peripheral information more than central information. If, indeed, the abstracted prototype is more "central" than the examples from which it was extracted, then a time delay should lead to more forgetting of the individual distortions than of the stored information concerning the prototype. An experiment was completed during the last period that demonstrated that recognition of the prototype was better than that of an old distortion after a week's delay between acquisition and pattern recognition. A second experiment was also completed in which a direct comparison was made between recognition tasks after a week's delay and after no delay. The results from the second experiment were less conclusive.

A post hoc analysis suggested a peculiar effect that might have accounted for the weak results of the second experiment. On the first block of trials in the recognition task the week's delay had apparently resulted in a much stronger loss for the old exemplars than for the prototypes. And this was in line with the theory. But, for some unaccountable reason, the successive blocks of testing in the recognition phase seemed to produce a marked "recovery" of the ability to recognize the old exemplars. It was as if the subjects had temporarily lost or forgotten the information about the original exemplars, but, by some unaccountable mechanism, had recovered this information after the first block of the testing phase.

Since this apparent recovery of the old exemplars occurred without any feedback, and since it was completely unexpected, another experiment was conducted during the present period to try to verify it. In this new investigation, the PDP-9 computer was employed to conduct the experiment. The recognition test was given either immediatley or after a delay of one week. Again there were four blocks of recognition tests with all of the test patterns being given once in each block.

If we just look at block 1, the old distortions showed a significant loss from immediate to delayed testing. And this tended to confirm the previous hypothesis that the information about the prototype is abstracted from the stored exemplars during the retention period. But, on subsequent blocks of the testing period, the old distortions again appeared to recover. The prototypes, on the other hand, showed no change over time.

Although this apparent recovery of the information about the old exemplars is hard to explain in terms of current views about memory and pattern recognition, and although it raises interesting questions about what sort of functional requirements, if any, such a pattern of retention could serve, it apparently cannot be attributed to some unaccountable artifact in this particular experimental setting since, as we will see below, Hyman and his colleagues have also encountered the same phenomenon in a somewhat different context.

On the basis of these experiments on the retention of abstract ideas, Posner and Keele have concluded that the stored prototype is quite stable over time, whereas the memory for the original exemplars seems to be less stable and subject to either permanent or temporary losses.

Keele, Posner and Fentress have also continued their experiments on the establishment of a boundary in classification learning. As Attneave (1957) has pointed out, subjects not only can learn the central tendency of a class pattern, but they can also learn something about the distribution and range of objects to which it can apply. The "schema" or stored representation of a given pattern includes not only the prototype, but criteria for deciding when a certain distortion of the prototype is still acceptable as an instance of the pattern.

If one of the bases for classifying new instances into an already established category is the degree of similarity to the prototype or central tendency of that category, then it should be possible to manipulate the boundary or cutoff point for accepting or rejecting a new pattern as a member of a given class. One determinant of the class boundary should be the degree of variability of the exemplars of the category--the more variable the exemplars the wider the boundaries.

To test this idea, subjects were exposed to either a low variability set of exemplars or a high variability set. Each set consisted of four dot patterns, presented one after the other on a computer-generated display. Immediately following the fourth exemplar, the subject was presented with a test pattern which he had to classify as either belonging to or not belonging to the same class as the first four exemplars. The earlier studies suggested that when the series of exemplars was highly variable, the subject had a higher probability of accepting the test pattern as an instance of the same class. At the same time, however, the data suggested that the subjects were able to make a more accurate discrimination between members and nonmembers of the class when the series of exemplars were of low variability. In terms of a signal detection analysis, the high variability seemed to produce a relatively generous criterion for acception patterns in a category, but at the expense

of a somewhat lower detectability. However, recent replications of the experiment, have not been complately consistent with this conclusion. Consequently further experiments are being conducted to clarify this issue.

The computer-generated dot patterns have also been used to study another important issue with respect to the abstraction of patterns. In these abstraction experiments, the subject sees, one at a time, a sample of exemplars all belonging to the same prototypical pattern. One might ask to what extent the subject's representation of the prototype is based on some sort of central tendency or average of the total set of examples he has witnessed and to what extent it is based upon the last exemplar he has seen. To get at this question, Keele and Fentress had the subject attempt to reproduce the prototype directly on the display tube by means of a light pen. The problem is to decide if the subject's reproduction is more similar to the prototype rather than to the last exemplar

At first this question was handled by having the computer print out the last exemplar, the prototype, and the subject's reproduced pattern for each series. Then a group of judges would rate pairs of patterns for similarity. But this procedure for collecting similarity ratings turned out to be practically and economically prohibitive. Lewis, however, has developed a program which enables the computer to calculate, for each pattern produced by a subject, its similarity to the prototype and the last exemplar of a given series. However, there have still been problems in obtaining reliable results. We hope that a combination of the computer-determined "similarities" and sub-jective ratings of "similarity" will eventually enable us to pinpoint the extent to which the subject has actually abstracted out the central tendency, as well as the degree to which his reproduction has been influenced by a parti-cular exemplar.

5.2. Learning of boundaries in dimensionial spaces

In the experiments of Posner and Keele, a hypothetically economical perceptual system can learn two things about a pattern that is called "A": (1) the prototype or central tendency of the class of all dot patterns that are A's, and (2) the boundary that sets off patterns that are included under A from those that are not. Given the type of stimulus materials used in these experiments, the central tendency would tend to elicit the quickest and most reliable recognition as an A; all other instances of A would be responded to more or less quickly and accurately depending upon their distance from the prototype.

Hyman, Nancy Frost, and Corrigan have initiated a series of experiments based on a similar pattern recognition paradigm, but in which the stimulus materials as well as the type of "pattern" or "concept" to be learned differ from those used by Posner and Keele. Whereas the efficient pattern recognizer in their experiments should compare instances with a prototypical pattern and classify them on the basis of their distance from this central tendency, the efficient pattern recognizer in the experiments by Hyman and colleagues should learn the boundary or plane in a hypothetical stimulus space that divides members of one class from those of another.

The stimuli are dot patterns and Munsell color patches. For experiments
in which a dot pattern is used, the entire stimulus space consists of dis-
tortions of one prototype. Unlike the preceding experiments, however, these
distortions are systematic instead of random. In the first series of experi-
ments the distortions of a pattern are created by systematically increasing
or decreasing the scale along the height axis and width axis independently.
The entire stimulus space consists, then, of a single dot pattern which varies
in height and width. The corresponding color space consists of a single red
hue (Munsell 5R) which varies on value (brightness) and chroma (saturation).

In the first experiment, the stimulus space consisted of 25 variations of
a dot pattern. During acquisition, four patterns were called "A" and four
were called "B". The arrangement of the exemplars in the total space can
be represented in the following chart:

```
               x A x x x
               A x A x x
     Height    x A x B x
               x x B x B
               x x x B x
                 Width
```

In this chart one can see that the four exemplars representing A differ from
those representing B by being tall and skinny. The subject's task is to
learn to associate A and B with the appropriate exemplars during the acquisition
period. Immediately after having mastered this task, the subject is tested
in a pattern recognition task in which all 25 patterns of the stimulus space
are presented one at a time, in random order. The subject classifies each
of the 25 stimuli by pressing one of two keys. He is given no feedback during
this test. Both speed to respond and the particular classification are recorded.

A first question is whether the subject learns to abstract out the
appropriate dimensions of height and width during the acquisition stage. Or
does he store the specific patterns representing each category. A third
possibility, in line with the experiments of Posner and Keele, is for the
subject to abstract out the central tendency of the four A's and the four
B's. As a matter of fact, there is no need to assume that the subject uses
just one of these particular strategies to the exclusion of the others. In
fact, Hyman predicted, on theoretical grounds as well as from pilot experi-
ments that early in acquisition the subject would store a unique representation
of each exemplar. As learning continued, however, he would gradually abstract
out features common to the four A's and features common to the four B's. With
further learning, or even during the recognition test, the subject might achieve
a higher level of abstraction and learn to classify patterns simply on the
basis of their position with respect to a hypothetical boundary drawn through
the two dimensional space of height and width.

Each of these strategies or stages should be detectable, during the recogni-
tion phase, in terms of efficiency of classifying any of the 25 stimuli. A
subject who has simply learned the exemplars by rote should show most efficiency
in classifying the eight original exemplars. One who has mastered prototypes

for A and B should be most efficient at classifying the patterns that represent
an average of the four As and Bs on the two coordinates. And, finally, one
who has mastered the two dimensional space, should show a gradient of increasing
efficiency of classifying either an A or B the farther either one is from the
hypothetical category boundary.

One problem with this approach is to find out where a particular
subject's category boundary is and to be able to correct the classifications
for distances from this boundary. Hyman solved this problem by developing a
procedure based on the discrimininant function. A computer program was
developed which finds the straight line that best corresponds to the boundary
that a subject was using in making his classifications; each stimulus is
assigned a distance in terms of its perpendicular position with respect
to this boundary. On the basis of the regression of classification time on
this distance function, the reaction times are corrected for distance so
that comparisons can be made to see if prototypes and exemplars still have
privileged statuses over and above their distances from the boundary. Within
this model, we can separately assess the variance in the classifications that
can be assigned to each of these separate types of recognition process--rote,
prototypical, and dimensional.

The results from the first experiment with 5 subjects indicate that, in
fact, the subjects were not abstracting out the dimensions of the space. Nor
was there any evidence for having learned or stored a prototype in the sense
employed by Posner and Keele. But, in line with the findings about the recovery of
information about the exemplars, the subjects began the recognition task
by seemingly displaying a relative loss on the original exemplars. By the
fourth block of trials, the exemplars had recovered or even improved with
respect to the other patterns. Although this effect was not expected it
was sufficiently striking and consistent across subjects that it probably
represents a real effect. Coupled with the similar finding of Posner and Keele,
it raises several interesting questions about the type of perceptual recognition
system that can apparently lose and then recover the ability to recognize
specific patterns.

In a second experiment with dot patterns, a deliberate attempt was made
to create conditions that would favor the abstraction of a dimensional concept.
Instead of 4 exemplars in each class, there were 6; and these were so chosen
as to demand a finer discrimination between the patterns. Since the new
task took longer to learn, a 24-hour interval was interspersed between
acquisition and subsequent testing. These changes worked in that the only
factor significantly determining subjects' classifications during the recog-
nition task was the distance of the stimulus from the category boundary. The
next step is to see which of the various factors operates to create this
transition to a dimensional concept and to discover at what stage in the
learning process it occurs.

Two experiments with color chips, paralleling the two with the dot
patterns have also been completed, but the analyses are not finished. It
does look as if subjects learn highly general aspects of the location of the
concepts in the color space, but they achieve this without storing any
specific information about the exemplars upon which they have learned.

6. MEMORY AND MEANING

In a sense, almost all of the work under the present contract can be
viewed as dealing with the relationship of perception and memory. The section
on the matching paradigm was much concerned with separating relatively immediate,
stimulus-bound aspects of processing from higher levels of processing that
are much more influenced by stored representations. And the section on
pattern recognition used a transfer design to try to characterize just what
the subject had stored in order to recognize patterns. Memory plays an even
more obvious role in the next section on motor performance since the major
emphasis of much of that work is on the role of preceding events upon present
performance. Certainly the theme of spatial representations under psycho-
physics deals with a type of memory, since the ability of a subject to
judge the magnitude of a stimulus must depend upon his ability to bring the
stimulus input into contact with some internalized scale. Under "meaning",
we will encounter still another type of memory whose function is to enable the
observer to interpret a given input in terms of an internalized context or
frame of reference.

The studies included in the present section focus upon the more tradi-
tional problems of memory and forgetting--interference, forgetting and decay,
mnemonic systems. In addition the problem of meaning and comprehension is
included here because, as the attempts to simulate comprehension have shown
(Reitman, 1965) to "extract" meaning from a stimulus input amounts to bringing
this input into contact with an enormous and highly structured long-term
memory store.

6.1. Short-term memory

Reicher is now in the process of putting the finishing touches to a series
of experiments aimed at studying the role of acoustic similarity in short term
memory. So many previous studies have demonstrated the interfering effects
of acoustic similarity, that it is now accepted as one of the key conclusions
about short term memory. Yet, with both visual and verbal presentations,
Reicher has been unable to find consistent effects of acoustic similarity. Part
of the apparent discrepancy is that Reicher was using a recognition instead
of a recall task. In a preliminary experiment, instead of requiring the
subject to indicate if a particular letter was or was not in the preceding
series, Reicher asked him if it was in a particular position. Under these
latter conditions acoustic similarity did seem important. Consideration of
these results has led Reicher to make a distinction between the relatively
uncoded trace of the stimulus and the relatively coded representation of it.
Acoustic similarity acts upon the coded representation and therefore may
not show up when the task depends upon recognition that can be mediated by
the uncoded trace.

Manard Stewart has programmed and debugged his procedure for examining the
process of absolute judgment in terms of a model of short term memory. He
has focussed upon the fact that transmitted information along a uni-dimensional
attribute has a low ceiling, usually 3 bits. Stewart's model assumes that
there is no representation of the value of the unidimensional stimulus in a
coded or symbolic form. For this reason the subject must work upon a trace or

image of the preceding stimulus. Since it is uncoded, it does not enter
long term memory. An implication of this is that the last stimulus seen
has the most important impact on judging the present stimulus. Stewart
has worked out several implications of this idea in terms of one and k-slot
models of memory. To tease out various alternative explanations about the
sequential effects that have been observed in this type of judgment Stewart
maintains that one must separately obtain absolute judgments and absolute
productions of the stimuli within the same experimental context. He has
just begun to collect the data and these will form the basis of his Ph.D.
thesis which should be completed during this coming period.

6.2. Long-term memory

The work of Posner and his colleagues on visual memory, the recent work
of Brooks (1967, 1968), and the theorizing of Hebb (1968) are among some of
the factors that have suddenly made the Zeitgeist responsive to the problem
of imagery. Up until the past year or so, the fantasy and imaginal aspect
of human cognition was completely neglected by experimental psychology. If
one was interested in imagery he might have found a sympathetic hearing in some
sections of clinical and dynamic psychology but not in the experimental
laboratory. Strangely enough the situation has almost reversed itself.
Clinical psychology has discovered behaviorism and more and more of the emphasis
is upon modifying overt behavior. To see what imagery is today, one must
turn to the experimental psychologists.

Atwood has begun a series of experiments for this Ph.D. dissertation that
focusses upon the role of imagery (visualization) in memory systems. His
first experiment studied the effects of either auditory or visual inter-
ference immediately after the presentation of a pair of words to be associated
by means of a visual image. Each subject was presented 35 pairs of words,
one pair at a time, whose corresponding members were to be associated in
memory. With each pair of words, Atwood specified the specific image that
the subject was to form in order to associate the two words. For example,
if one word pair was NUDIST and BIRD, the instructed image might be given by
the phrase: "Nudist devouring a bird." For each such pair the subject was
instructed to try to visualize the stated relationship. This type of mnemonic
system seems quite effective since in a pilot study, subjects averaged 28
correct recalls of the 35 pairs.

In the experimental conditions an "interfering task" was administered to
each subject immediately after he was given each word pair to image.   In
the Visual interference task, immediately after the subject was given the
pair to be imaged, the numeral "1" or "2" was displayed, and the subject had
to respond with either "1" if "2" was displayed, or "2" if "1" was displayed.
In the Auditory interference task, the digits "1" or "2" were spoken rather
than displayed visually. The twenty subjects in the visual interference
condition averaged 1.5 errors while the twenty subjects in the auditory
interference condition averaged only 9 errors out of 35 pairs. There was
practically no overlap between the two groups and a median test yielded a
level of significance of .0002.

This finding is consistent with Atwood's hypothesis that the formation
of the visual image requires some time to form and uses some or all of the

capacity of the visual system. One possible explanation for the results is that in order to perform the visual interference task, the subject had to temporarily postpone formation of the image until he had employed the limited capacity of the visual system to determine if the displayed numeral was a "1" or "2". this disruption or slight delay was sufficient to cause more forgetting in the visual condition than in the auditory.

But there is another possibility. It may be that both the visual and auditory interference tasks have their major effect on the same central processing system rather than on different modalities. If this were so, then the greater impact of the visual task might be attributed to the possibility that it makes greater demands upon the central processing system than does the auditory version. Atwood's second experiment was designed to investigate this latter possibility. If one could show, for example, that the visual task did not interfere more than the auditory one in a situation in which visualization is not called for, then one could maintain that the second possibility was not accounting for the results.

Experiment 2 used the same design as Experiment 1 except that the word pairs were selected to be deliberately low on visual imagery (Paivio, Yuille, and Madigan, 1968). Because these low-imagery pairs were more difficult to learn, only 21 pairs were employed. The subjects were given each pair one at a time, embedded in a sentence which was deliberately formulated so as to make it improbable that the subject would employ visual imagery. Some examples were: "The velocity of light has great magnitude."; "The intellect of Einstein was a miracle." Immediately following each presentation of a word pair, the auditory or visual interference task was administered as in Experiment 1.

All the subjects have not been run as yet, but the partially completed experiment seems to provide clear evidence that under these conditions the visual task does not interfere more with the subsequent recall. In fact, the results so far suggest that for these word pairs the auditory task interferes significantly more than does the visual task. This suggests that in Experiment 2, the subjects were coding and storing the information in an auditory form.

This first step in the study of imagery, along with the consulting visit of Brooks to our laboratory during this period, has encouraged us to further pursue the role of imagery in coding behavior. Reicher is now conducting a seminar on Imagery for our group, and he is planning a series of studies on the topic.

6.3. Meaning and comprehension

Schaeffer and Wallace have completed and submitted for publication the first of a series of studies on semantic similarity and how it is mediated (1969). The first experiment applies the matching paradigm of Posner and Mitchell (1967). The subject is shown a pair of words. He is instructed to press a reaction key to indicate "same" if both words denote living things, or if both words denote non-living things. Otherwise he presses the reaction key which indicates "different". The living things could be either mammals or

flowers; the non-living things could be metals or fabrics. The object was
to see if it takes less time to recognize two words as the "same" if they
both represent mammals than if one represents a mammal and the other represents
a flower (for example, is it easier to recognize "lion-squirrel" as both
"living" than "lion-pansy"). The results clearly show that the subject needs
less time to recognize two mammals or two flowers as the same than when one
word is a mammal and the other is a flower. The same holds true for two fabrics
and two metals when compared with a metal-fabric pair.

The first experiment demonstrated the effect of semantic similarity on
facilitating the recognition of two words as belonging to the same category
The second experiment was designed to demonstrate the effect of semantic
dissimilarity upon the speed of classifying a word into its appropriate
superordinate category. Prior to each trial, two category labels such as
"Bird" "Mammal" were displayed. This was followed by a single test word,
such as "wren". The subject's task was to classify "wren", as quickly as
possible, into one of the two given categories for that trial. Here the goal
was to see if a word such as "wren" could more easily be classified as a
"bird" when the accompanying alternate was "fruit" instead of "mammal".
The results were highly significant and indicate that semantic dissimilarity
between the categories aids in the classification of a given word.

These studies form the opening wedge in what Schaeffer hopes will be
a new way to attack the elusive, but important question of how memory is
organized in terms of semantic as well as formal aspects of verbal material.
The use of discrimination latencies within this paradigm seems to provide
an especially sensitive tool for studying semantic coding systems and how
semantic classifications enter into the determination of meaning in contextual
situations. Schaeffer is currently running a series of experiments employing
this paradigm. A copy of the report on the first two experiments is included.

Keesey has finished collecting the data for his doctoral dissertation
on "Comprehension and Distortion of Meaningful Material at Controlled Rates."
This represents one of our first attempts to apply some of the ideas and tools
of our work on memory directly to contextual material in a quasi-natural task.
The problem was to see how different measures of the retention of prose material
would be affected as the subject was forced to read the material at various
rates above his normal pace. On the basis of some of his own work as well as
that of others, Posner (1965) has hypothesized that some types of retention
could be facilitated or unaffected by increased rates of exposure while others
could be seriously impaired. In the former category would be simple recall of
words, while in the latter category types of comprehension that involved
processing or transforming the material while reading.

Keesey had his subjects read three "stories" in which the relationships
between various individuals and groups could be stated in set relations of
inclusion, exclusion, partial overlap, etc. Both his stories and his measures
of comprehension based on set relations were based upon the work of Dawes (1964,
1966). The questions based on set relations required a form of comprehension
that reflects a relatively high order of transformation or processing of the
material that was read. In an attempt to get a measure of retention that would
reflect a low level of processing or transformation of the material, the subjects

were also given a test based on the cloze procedure--they were given actual
sentences from the material that they had read, but with missing words which
they had to supply.

Keesey found that as the rate of the reading went from 0 to 200 words
per minute above normal pace, the discrepancy between the set questions and
the cloze procedure increased significantly. Most of this discrepancy was due
to drop in ability to answer set questions at the fastest reading rat...
Unfortunately, the cloze procedure seemed to be an insensitive measure in
this situation since even the control subjects did quite well in filling in
the blanks. Consequently, it is not clear if there was a differential effect
upon retention depending upon the type of transformational task.

7. MOTOR PERFORMANCE

As Keele has pointed out in his important monograph on movement control
in skilled motor performance (1969), the study of movements not only has
implications for understanding skilled motor performance but also for under-
standing "nonmotor" skills such as thinking, memory, perception and imagery.
What the focus on movement yields is an increased appreciation of the role of
temporal integration in all human performance. Many of the new directions in
the stimulus processing areas of our project have emphasized "spatial inte
gration" (i.e., how the individual organizes and deals efficiently with the
multiple inputs from a display); the topic of this section complements this
emphasis by emphasizing the organization of acts that are performed sequentially.
In helping to comprehend the accomplishment of highly skilled sequential acts,
the concept of motor program is becoming increasingly useful.

The work to be reported in this section is divided into two rubrics.
Under the first heading are a series of reaction time studies all concerned
with the repetition effect--the apparent facilitation of a given response when
that response is repeated within a series of responses. This effect has
taken or importance for us because it has many properties in common with
short-term memory (Keele, 1969). In addition, it seems to be a promising tool
for dealing with the question of whether automatized acts can ever dispense
with the need for central processing.

In the second category are studies in which subjects make movements of
varying lengths and demanding varying degrees of precision. One aspect of
these movements is the type of memories and coding systems which they entail.
Some kinds of motor memory seem to follow laws of forgetting which may differ
in important ways from those found for verbal and visual material. A second
aspect is the amount of "attention" a movement demands at various stages
of its execution. Does the individual, for example, have to monitor the
movement at all stages?

7.1. Reaction time

Hyman reported a study on the repetition effect at the Donders Centenary
Symposium at Eindhoven, Holland last July (Hyman & Umiltà, 1969). A copy of
the paper, which was not ready for inclusion with the last report, is included
with the present report.

Kornblum (1968), on the basis of his own experiments on serial reaction time, concluded that "the information hypothesis must be rejected as ar erroneous and misleading interpretation of serial choice RT." At the Donders Centenary, as well as in a later technical report (Kornblum, 1968b), he extended this conclusion to the application of the information hypothesis to all choice reaction time. Part of the argument depends upon Kornblum's belief that he can reduce all cases in which the information hypothesis apparently works to a confounding of information measures with the probability of a repetition.

Hyman and Umiltà have pointed out that the information hypothesis states what should take place under ideal or optimal processing. It states tha* "all other things being equal (such as stimulus-response compatibility, training, discriminability, and error rate), equi-information conditions must produce equal overall mean RT's" (Kornblum, 1968). The empirical basis for Kornblum's argument relies chiefly on his ability to find two equi-information conditions that did not produce the same overall mean RTs.

Hyman and Umiltà observe that Kornblum's experimental situation was far from optimal. The subjects had far too little practice; they had to deal with eight different, highly similar conditions within each one-hour session; and the extremely brief interstimulus interval of 140 milliseconds almost certainly does not give the subject sufficient opportunity to process the sequential information that Kornblum has built into the stimulus series. What Kornblum did demonstrate was that, with the restrictions imposed upon his subjects, they apparently were unable to profit from information in his high alternation conditions, but did profit from the sequential information in his high repetition conditions. If the subjects were given more opportunity to profit from the information in the preceding stimulus series, would their performances approximate what the information hypothesis predicts for optimal information processing?

To see what would happen under conditions somewhat more "ideal" than those employed by Kornblum, Hyman and Umiltà employed only three of Kornblum's eight conditions--one pair of equi-information conditions of one high and one low repetition situation and one condition of four equi-probably alternatives without sequential constraints. By choosing conditions easily discriminable from each other and by restricting the total set to just three conditions the possibility of confusions or interference between conditions was lessened In addition, the interval between response and succeeding stimulus was approximately 7.5 seconds or more than 50 times that employed by Kornblum.

The results for eight subjects averaged over the last three days (the first day was practice) are presented in the following table:

Overall Mean Reaction Time

Condition	Information	Mean RT
No constraints	2.00 bits	455 msecs
High alternation	1.58 bits	430 msecs
High repetition	1.58 bits	416 msecs

All three means differ significantly from each other. They indicate that under these more "ideal" conditions the subjects were capable of using the sequential

information in the alternations, but they apparently were unable to use such information as effectively as they could use the information from repetitions. This, in turn, would indicate that there is something that impedes optimal extraction of the information in the high alternation condition.

Although the overall means still show the repetitions as faster than the alternations, the data suggest that the difference between these two conditions is lessening with practice. Furthermore, there were large individual differences. By the fourth day (there was one day of practice followed by four experimental days), two of the eight subjects were faster under the high alternation condition (although not significantly so) and for five of the eight subjects the absolute difference between the conditions was negligible (an absolute difference of eight milliseconds or less). Therefore, the residual difference between the high alternation and high repetition conditions can be attributed to three of the eight subjects. Under optimal conditions at least some subjects behave according to the information hypothesis.

As has been mentioned, the data indicate that the information in the high alternation condition seems relatively difficult to extract in comparison with that in the high repetition condition. Hyman and Umiltà (1969) point out two possible reasons for this difficulty; both of these are confounded in Kornblum's experiments (1969a, 1969b). One possible reason is that a repetition, in itself, is facilitated with respect to making a response to a stimulus that differs from the immediately preceding one. This is the "repetition effect" that Kornblum bases his theorizing upon. Another possible reason, however, is that Kornblum's high repetition condition was one that confronted the subject, on each trial, with a subjective probability distribution with one clear mode--there was just one most probable alternative on each trial. The subject had merely to set himself to respond to this most likely alternative. The high alternation condition, on the other hand, always presented the subject with a multimodal condition--there were always three of the four alternatives that were just as probable and one that was improbable. Thus, Kornblum confounded repetitions with shape of the subjective probability distribution.

In a second experiment, Hyman, Umiltà and Trombini (1969) compared two different high alternation conditions with the high repetition condition. The same four alternatives were used and the same repetition and high alternation conditions from Kornblum's experiment were employed. In addition a high alternation condition was used that had the same single modality at the high repetition condition--i.e., on each trial the subject was always faced with a distribution in which only one of the four alternatives was highly probable, but that alternative was the succeeding stimulus in the array rather than a repetition. The mean reaction times from the last two days (out of five days) for 9 subjects are presented below:

Condition	Information	RT on Day 4	RT on Day 5
High repetition	1.58	409 msecs	397 msecs
High alternation (multimodal)	1.58	445 msecs	428 msecs
High alternation (unimodal)	1.58	409 msecs	395 msecs

For these subjects, the high alternation condition from Kornblum's experiment is still slower than the high repetition condition after five days. However, the new high alternation condition shows the same average reaction as does the high repetition condition. This result shows that under the conditions of the present experiments the apparent difficulty of the high alternation conditions has nothing to do with the repetition effect. Rather it reflects the difficulty that subjects have in preparing to respond to a situation in which several possibilities are equally likely as compared with a situation in which one possibility is clearly favored. But even here there are again individual differences. At the end of the five days of practice there is no difference between the repetition and the multimodal condition for three of the nine subjects.

The results of the preceding two experiments do not demonstrate that there is no repetition effect. Rather they emphasize what Hyman (1953) pointed out many years ago with respect to the repetition effect. In that early study he demonstrated that there were at least two processes functioning to determine the reaction times on the basis of preceding trials. One process was the effect of a simple repetition upon the succeeding response. This latter process seemed to occur automatically and often counter to the subject's overt expectations. The second process was a conscious expectancy or guess at what the next signal would be; this latter process often revealed itself as faster reaction times to signals that had not occurred for quite a while within the series. It stands to reason that when there is adequate time between trials, the role of expectancy and subjective strategies will play an important part in determining reaction time to particular signals. When the intertrial interval is very short such that it prevents the operation of rehearsal and complex transformational processes, then we would expect the simple repetition effect to predominate. Expectations such as these were partially responsible for the next series of experiments.

Keele, Boies, and Buggie have just finished an experiment on the repetition effect in which they used the computer-aided automatic laboratory. The repetition effect, in itself, is only a side issue in these experiments. The general context is the question of processing limitations in a serial task. An outstanding characteristic of serial tasks in daily life is the redundancy in the sequence--an element in the series is partially predictable from preceding elements. An important question is whether the use of redundancy can become "automatic"--especially for highly practiced, very familiar activities. In other words, can such sequential information be used without employing some of the capacity of the central processing system?

Keele and his associates used a serial reaction task with four alternatives. Three conditions of stimulus generation were used: (1) all four alternatives are equally likely on each trial; (2) a high probability of repetition (1.58 bits); (3) a high probability of alternation (1.58 bits). The high repetition condition is that same as employed by Kornblum, but the high alternation condition is the unimodal situation used by Hyman, Umiltà and Trombini. A second variable was the interval between response and succeeding stimulus. The experiment included four such intervals: 0, 125, 250, and 500 milliseconds.

The experimenters predicted that at the very short intervals, the use of sequential information would become very inefficient. This was predicted only for the high alternation condition rather than the high repetition condition. The data are not completely analyzed, but overall means suggest that the high repetition condition shows an advantage over the two conditions at 0 seconds and maintains this advantage up to 250 milliseconds. From 250 milliseconds up, the high alternation and the high repetition conditions are equally fast and both enjoy a significant advantage over the equally-likely case.

In subsequent experiments, Keele and his associates will increase the difficulty of processing sequential dependencies in various ways to see what the optimal intervals between response and stimuli should be for each case. Furthermore, they plan to extend this paradigm to highly practiced skills such as typing.

Eichelman has completed and submitted for publication a study in which he tried to separate stimulus from response repetition effects and study their relative contributions at short and long response-stimulus intervals (1969). His point of departure was the apparent similarities between the work of Posner, Keele and associates on separating out the effects of physical identity from name identity matches in the matching paradigm and some of the theorizing by Bertelson (1965) on what is taking place in the work on the repetition effect. Eichelman had his subjects call out the name of a displayed letter as fast as they could. The dependent variable was the time to respond. On each trial the subject was presented with one of the letters, A, B, F, H, K. They could receive either the upper or lower cases of these letters. A trial on which A appeared, for example, would provide data for stimulus repetition if the preceding trial had presented upper case A or data for a response repetition if the preceding trial had presented lower case a.

The experiment was conducted with two different intervals between one response and the succeeding stimulus presentation--200 and 700 milliseconds. Eichelman hypothesized that there would be a decrease in the advantage of the stimulus repetition over the response repetition as the response-stimulus interval increased. His results clearly support this expectation. At 200 milliseconds there is an advantage of 48 milliseconds in favor of the stimulus repetition condition. This advantage has declined to 22 milliseconds by the end of 700 milliseconds. Interestingly enough, at 200 milliseconds, the total repetition effect seems to be mainly due to the stimulus repetition. This total repeition effect is approximately the same size at 700 milliseconds, but now seems mainly due to the response repetition.

Eichelman concludes that "the repetition effect is a function of at least two components which may work in opposite ways in affecting the absolute RT's for the different classes of repetitions, thereby, affecting the differences among them. The first is a stimulus identification component which depends primarily upon the visual information available from the immediately preceding stimulus, and not on a strategy to test for the presence of the preceding stimulus first. The second is the ability for the subject to make the correct response. This depends upon refractoriness of decision making processes as well as muscular and skeletal apparati used in making the response, and whether the

subject has prepared to make the response."

The similarity between the matching paradigm experiments and the results of the present experiment seems to be that in both types of experiment physical identification processes can act so as to facilitate responding or can be impeded by additional requirements. In the matching task, the additional time for a name identification reflects the addition of the naming stage to the physical identification stage. In this repetition effect experiment, however, the advantage of the stimulus repetition over the response repetition, however, lies in the subtraction from the process of the time ordinarily required to "read-in" a physical stimulus. In this sense, the current findings of Eichelman have much in common with the results of Taylor's dissertation.

A copy of Eichelman's paper is enclosed.

7.2. Directed movements

Although the analysis of the memory codes and the attentional demands of controlled movements is an important component of our research efforts we do not have much in the way of results to report form the last period. We have continued our efforts, but these have been mainly in building and testing of apparatus and methodology which will be necessary for experiments we are planning to do. In addition, we have been spending time in mastering knowledge that will prepare us for using computer-aided experiments and computer-converted data in the study of movements. Posner is currently preparing a paper on "Reduced attention and the performance of 'automated movements'." This should be ready for the next report. Keele and Ells have just completed collecting the data for their study on cues for movement reproduction. The data should be analyzed and ready for the next report. And the equipment has been built and debugged for Ells' doctoral dissertation on "Attentional demands and components of skilled motor performance." He has just begun collecting the data. Although Ells does not expect to finish until August, a partial summary should be ready for the next report.

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13. ABSTRACT

The output of research during the last half of 1968 has continued the pace set by the previous year. The present report reviews some of the results from projects which were completed or in progress during this six-month period. In many ways this period can be viewed as a time of transition. While we continued to develop the paradigms and themes of the preceding year, we devoted much of our time towards developing the methodology, hardware and technical competence to extend our efforts towards new problems. Some of these new problems include the role of imagery, the control systems of serial behavior, natural languages, the problem of meaning, decision processes, automated tasks, skilled performance in naturalistic settings, etc.

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